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(54) IMPROVEMENTS IN OR RELATING TO LIQUID-SPRAYING DEVICES HAVING A NOZZLE SUBJECTED TO HIGH-FREQUENCY VIBRATIONS

(71) We, THE PLESSEY COMPANY LIMITED, a British Company, of 2/60 Vicarage Lane, Ilford, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the spraying of liquid fuels and other liquids and has for an object to provide improved spraying devices of the kind in which vibrations of what will hereinafter be called ultrasonic frequencies are applied to a liquid-emitting jet-forming nozzle in the direction of the jet, in order to break up the jet to form the desired spray. While there would not appear to be a direct relation between the range of frequencies which will ensure a satisfactory break-up of the jet and the frequency corresponding to the upper limit of perception by a normal human ear, the term ultrasonic frequency is nevertheless used in the present specification as meaning a frequency high enough to produce a satisfactory break-up of a liquid jet. This appears justifiable because on the one hand a satisfactory break-up cannot generally be achieved by frequencies very much lower than the maximum frequency perceptible by an average human ear, and particularly because in practice a frequency ... ve that limit of perception will generally ... ployed in order to avoid the creation ... necessary audible noise.

Although it has been found possible to break-up a jet of liquid emitted by a nozzle into a very fine mist by the application to the jet of ultrasonic vibrations in the longitudinal direction of the jet, a satisfactory degree of such break-up has so far been achieved in that manner only at some considerable distance from the nozzle exit. We believe that this is due to the fact that the vibrations in the first instance break-up the solid jet into a relatively small number of separate packages, and only subsequently is each of these packages resolved into mist-like droplets by mechanical interaction with the air into which the jet is emitted.

According to the present invention in a spraying device of the kind referred—to break-up of the jet into a fine mist can be achieved with very much less requirement in air space if a non-vibratory impact surface which faces the jet so as to be impinged-upon, when the vibrator is operated, by the packages of liquid resulting from the break-up of the jet, is arranged at a distance from the nozzle which is short compared to the distance required for the packages of liquid formed by the break up of the jet to be resolved into mist-like droplets by mechanical interaction with the gaseous atmosphere. The distance of the impact surface from the nozzle may, for example be about 6 millimetres. When the vibrator is operated, the vibration of the nozzle will break-up the jet emitted from the nozzle into separate packages, one package being delivered for each cycle of vibration, and as each package impinges upon the impact surface, the package will itself break-up into a fine spray of droplets. If the impact surface is perpendicular to the jet axis, this spray will emerge uniformly round that axis. If on the other hand the impact surface is inclined to the axis of the jet, the spray will emerge at an angle to the jet axis, so that suitable three-dimensional shaping of the impact surface may be employed to break-up the jet into a pre-arranged spray pattern.

The invention is believed to be of particular advantage when used in combination with the invention described in our co-pending G.B. application No. 32009/69, Serial No. 1,311,879, in which a nozzle equipped with an ultrasonic vibrator is arranged to emit continuously a normally solid jet of liquid directed at a collector aperture. This aperture is generally provided at the end of

a collector tube, and while normally substantially all the liquid of the jet is withdrawn through this aperture from the air-filled chamber into which the nozzle is directed, when a pulse of ultrasonic-frequency vibrations is applied to the nozzle in its axial direction, the jet is during the pulse of the vibrations, broken-up into a fine spray which becomes mixed with the air in the chamber in question. We have found that the effectiveness of this device to form a fine spray is greatly enhanced if the end of the collector tube, or some other surface surrounding the collector aperture, is formed as an impact surface in accordance with the present invention. If this is a plane surface perpendicular to the axis of the jet, it will produce a fine spray of droplets which will emerge at an angle of about 20° to the axis uniformly round the collector aperture.

According to a preferred feature of the invention, at least part of the impact surface is inclined at an angle to a plane normal to the axis of the jet, with the result that the spray produced from any portions of liquid striking such part of the impact surface will emerge from the impact surface at an angle different from the normal 20° angle, so that by suitable shaping of the impact surface within the impact area the spray achieved may be adapted to requirements both as regards its direction and angle and as regards its cross-sectional shape. This may be utilised direct the produced spray from one chamber through an aperture of the wall thereof into another chamber. Thus if the end of a collector tube, or an impact surface surrounding a collector orifice, facing the nozzle jet, has the shape of a symmetrical wedge whose edge extends diametrically across the axis of the orifice and jet, a spray pattern can be produced which has the appearance of a fan covering an angle of about 90° in a plane normal to the edge of the wedge, while on the other hand if the impact surface is arranged throughout at an angle to the axis of the jet and collector aperture, the spray will be deflected throughout in the direction of inclination by an angle determined by the angle of inclination of this impact surface. Both these forms of the invention have been tried experimentally and no appreciable deterioration in the regularity of the spray droplets was noticed when carrying out these experiments.

In order that the invention may be more readily understood, two embodiments of ultrasonic spray devices incorporating the invention will now be described with reference to the accompanying drawing, in which Figure 1 is a somewhat diagrammatic elevation showing an arrangement producing two fan-shaped sprays forming an angle of about 90° with each other, and

Figure 2 similarly shows an arrangement which produces a single spray deflected to one side of the axis of the collector tube.

Referring now first to Figure 1, liquid fuel is supplied from a suitable source, not shown, to a pipe 1 entering the neutral zone of a piezo-electric vibrator nozzle 2. This nozzle ends in a sharp-edged orifice 3 and is equipped with a piezo-electric ceramic element 4 arranged for the generation of vibrations in the longitudinal direction of the nozzle when the element is energised, approximately at its resonant frequency, by a source 5 of alternating current of ultrasonic frequency as hereinabove defined. The nozzle is arranged to produce a jet 6 leaving the sharp-edged orifice 3 in the axial direction of the nozzle, and when the piezo-electric element 4 is energised, this jet becomes fragmented. Facing the nozzle in the axial direction is a collector tube 7 which, not being connected to the element 4, does not vibrate, and which is arranged to intercept the jet, when the latter is integral in the absence of ultrasonic vibrations, for return to the fuel source. The collector tube 7 is formed, at its end facing the nozzle, with a head 8 in the shape of a wedge symmetrical to the axis of the collector tube 7. When the ceramic element 4 is energised to produce ultrasonic vibrations, the jet becomes fragmented, and the greater part of the fuel packages formed from the jet will strike the two wedge surfaces of the wedge-shaped head 8. The succession of fuel packages will be transformed on these non-vibratory surfaces into two sprays 9, 9 of fine fuel droplets. Each of these sprays is concentrated over a narrow angle, and the two sprays are spaced from each other symmetrically by a very much larger angle 10 arranged symmetrically to the joint axis of the nozzle 2 and collector tube 7. To show more clearly the effect of the wedge-shaped head body 8, the angle that is covered by the spray of droplets when employing a plain, square-ended collector tube 7 without a head 8 has been indicated at 11.

The arrangement illustrated in Figure 2 is similar to that of Figure 1 as far as the operation of the nozzle 2 and its vibrator 4 are concerned and also as regards the coaxial arrangement of the nozzle and the collector tube, which latter in this embodiment bears the reference number 17. At its end facing the nozzle 2, however, the collector tube 17, instead of being provided with a symmetrical head as shown at 8 in Figure 1, is cut off along a plane surface 12 inclined, to the axis of the collector tube 17, at an acute angle of such value that, when the vibrator 4 is energised, the fuel packages, on striking the non-vibrator surface 12, will be transformed into a fine spray 13 arranged about an axis 14 which is inclined by an angle 15 from the axis of the collector tube 17.

The arrangements of the present invention,

more particularly those described with reference to the accompanying drawing, may be employed in fuel systems for internal-combustion engines, for example in a manner similar to those of the fuel system described in the above-mentioned application No. 32009/69, and in other fuel systems intended for combustion chambers of various types of gas turbines.

WHAT WE CLAIM IS:—

1. A liquid-spraying device in which a nozzle, arranged to inject a jet of liquid into a gaseous atmosphere, is equipped with a vibrator for producing, when operated, ultrasonic vibration as hereinabove defined of the nozzle in the direction of the jet and thus breaking-up the jet, and wherein a non-vibratory impact surface which faces the jet so as to be impinged-upon, when the vibrator is operated, by the packages of liquid resulting from the break-up of the jet, is arranged at a distance from the nozzle which is short compared to the distance required for the packages of liquid formed by the break-up of the jet to be resolved into mist-like droplets by mechanical interaction with the gaseous atmosphere.

2. A liquid spraying device as claimed in claim 1 for an internal-combustion engine fed with a fuel-and-air mixture, in which the nozzle is fed continuously with fuel and is arranged to direct its jet of fuel to a collector aperture leading to a fuel-return line, while the vibrator is arranged to be energised during a fraction only of each revolution of the engine, wherein the end of a collector tube, or some other surface surrounding the collector aperture, is formed as an impact surface for impacting contact by fuel packages of the broken-up jet when the vibrator is operated.

3. A liquid spraying device as claimed in claim 1 or claim 2, wherein at least part of the impact surface is inclined at an angle to a plane normal to the axis of the jet.

4. A liquid spraying device substantially as illustrated in, and described with reference to Figure 1 or Figure 2 of the accompanying drawing.

5. An internal-combustion engine having a fuel-injection system that includes a liquid-spraying device as claimed in any preceding claim.

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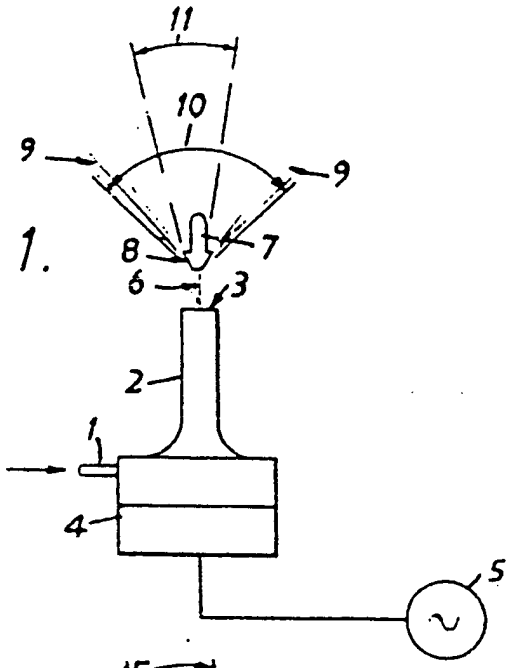

FIG. 1.

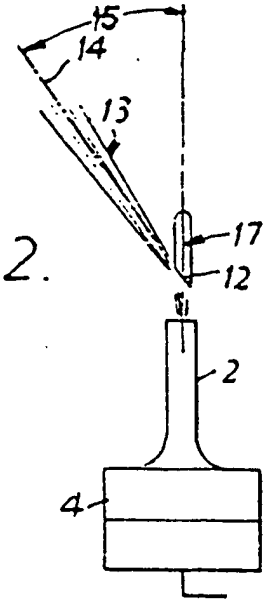

FIG. 2.